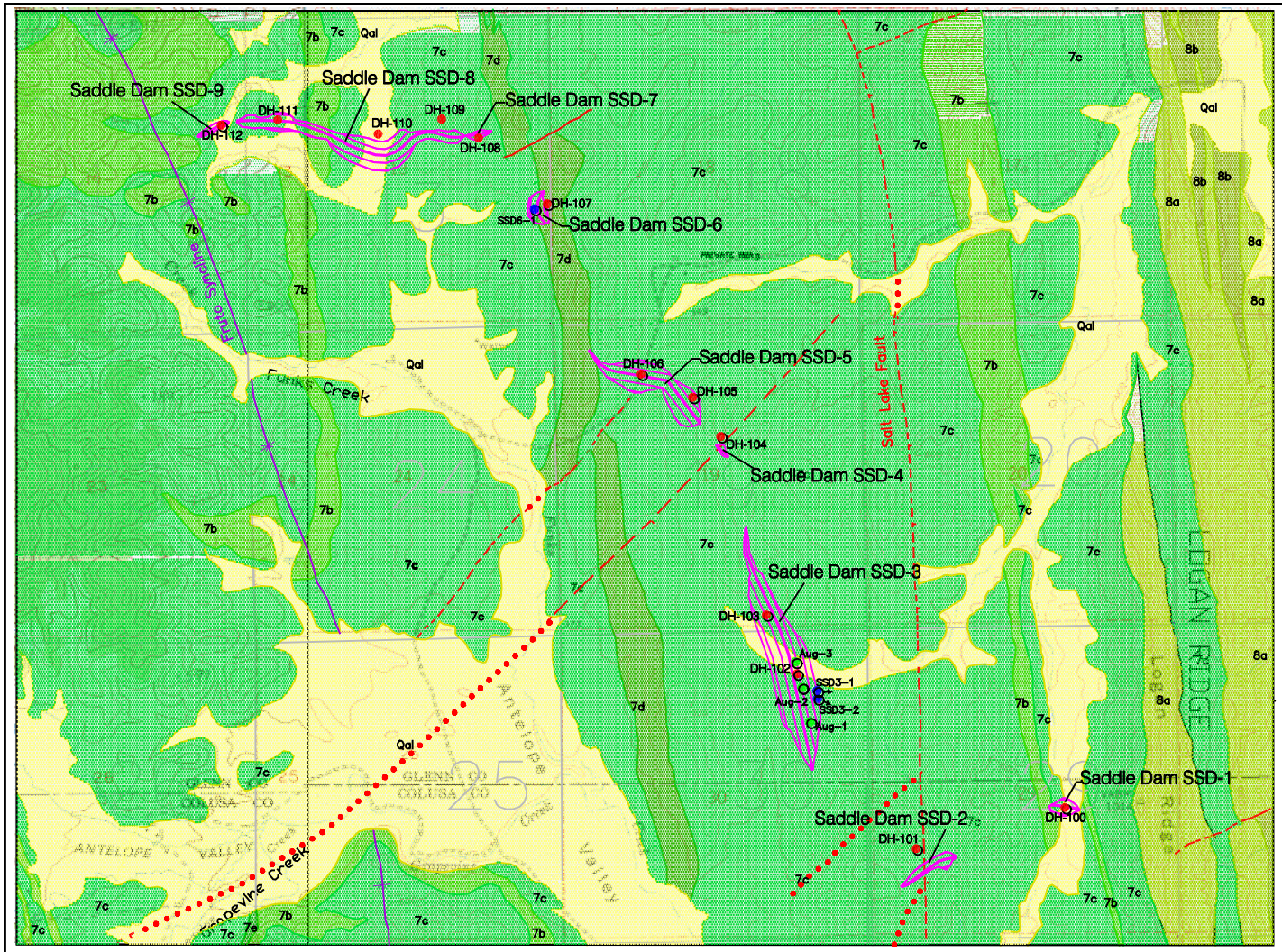
Northern Sites Saddle Dam Sites

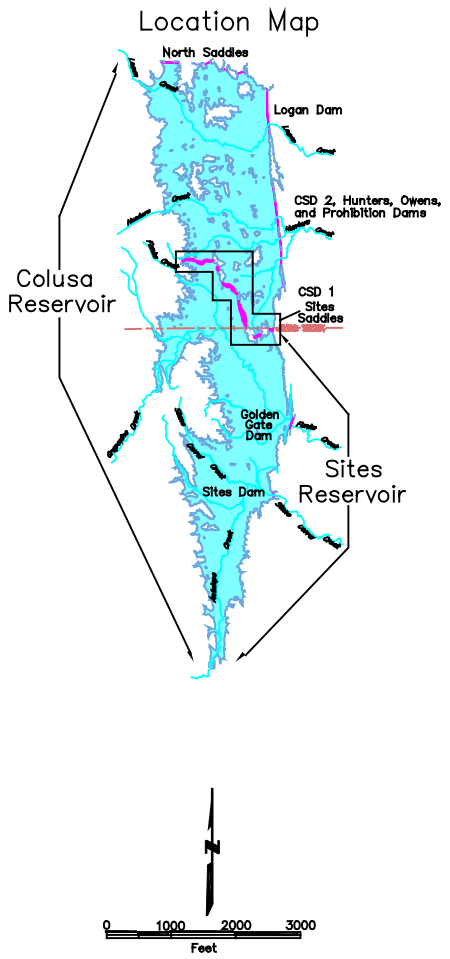
Northern Sites saddle dam alignments are located between the Sites and Colusa compartments of the proposed Sites and Colusa Reservoirs, roughly along the Glenn-Colusa County line. It is in portions of Sections 13 and 14, T18N, R5W, and Sections 18, 19, 29, and 30, T18N, R4W on the Logan Ridge and Lodoga 7.5-minute USGS topographic quadrangles. These nine alignments total 13,925 feet in length and would be built along a 4-1/2-mile long reach that will constitute the northern reservoir rim of the proposed Sites Reservoir. These nine saddle dams vary in elevation from 410 to 480 feet. The saddle dams will range in length from 350 to 4,600 feet, and in height from 19 to 130 feet (Figure 7).

Previous geologic work was performed by USBR in the early 1960s with additional work in the early 1980s. USBR proposed 12 dikes as part of its 1964 investigation for a smaller reservoir. Because the current DWR design is for a higher water surface elevation, some of its saddle dams will merge; i.e., the crest elevation would be close enough to the top of the ridge that it will be necessary to combine adjacent structures into a single dam. Because of this, DWR is investigating 9 saddle dam locations that correspond to the 12 USBR dikes. USBR developed 1:1,000 topographic contour maps, augered 13 holes to bedrock at these locations, and placed piezometers to monitor groundwater elevations. Copies of USBR drill logs are available in Technical Memorandum A. The current investigation by DWR's Northern District and Division of Engineering consists of reconnaissance-level geologic mapping, selected diamond core drilling, and augering of saddle dam sites number 3 and number 6. This work supplements the original USBR investigation; however, more fieldwork is recommended prior to final design and construction.

Alignment Geology

The geology of the area consists of a series of interbedded mudstone, sandstone, and conglomerate units of the Great Valley sequence. These trend roughly north-south with a dip that varies from west to east. The Fruto syncline just borders the northwestern end of the 4-1/2-mile reach near DWR saddle dam number 9 with moderate westerly dips on the eastern limb. These dips change from westerly to easterly southeast along the alignment since the Sites anticline intersects the eastern portion of the alignment. The alignment lies mostly within mudstone and siltstone of the Boxer Formation with some scattered sandstone interbeds. These are more resistant and form scattered outcrops along the alignment but were not considered mappable at the scale used during this reconnaissance-level investigation. These outcrops are probably discontinuous along strike although visual correlation is difficult because of the thick clayey soil overburden. A distinctive massive to thickly bedded conglomerate unit crops out near several of the saddle dam sites, especially along the western portion of the alignment.





Legend

Quaternary Units

Inconsolidated clay, silt sand and gravel, poorly sorted, corly to well stratified, floodplain and streambed deposits.

Qal Quaternary Aluvium

Cortina Formation

Sandstones, siltstones,and conglomerates, thinly bedded to massive, light gray in color, contains fossils, arkosic, fine to coarse grained.

Venado Sandstone Member

8a Sandstone

8b Interbedded Sandstone and Siltstone

Boxer Formation

Sandstone,siltstone, marine slump and conglomerates, thinly bedded to massive, arkosic and containing fossils,sandstones and siltstones are graded and show convolute bedding, conglomerates are poorly sorted and thick bedded.

7a Sandstone

7b Interbedded Sandstone and Siltstone

7c Siltstone

7d Lower Conglomerate

7e Upper Conglomerate

Symbols

Fault trace - Dashed where inferred, dotted where covered

Facies Contact

Formational Boundary

Syncline

USBR DH-109

DWR SSD3-1

Drill Hole Location, showing bearing and horizontal projection. Open if proposed, closed if completed. Angle is from horizontal.

DWR Aug-3

DWR Auger Hole Location. Open if proposed, closed if completed.

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF WATER RESOURCES
NORTHERN DISTRICT

SITES SADDLE DAMS

LOCATION & GEOLOGIC MAP

OF THE

NORTHERN SITES SADDLE DAM SITES

FIGURE 7

Filename:N:\NDSharedInfo\typing\geo\Final 1999 Sites Report\Figures\original\Figure 7--Sites Saddle Dams Loc and Geo--01-19--01--JHM.dwg
Layout Name:Layout1 Plot Time: Jan 19, 2001 - 4:02pm

The proposed saddle dams would be built entirely on north-trending, east-dipping Cretaceous sedimentary rocks of the Boxer Formation. This formation consists primarily of mudstones with some interlayered sandstone and conglomerate lenses. The more resistant conglomerates, sandstones, and siltstones form ridges that dominate the local topography. Colluvial cover on the ridges averages up to 5 feet in depth. Alluvial and terrace deposits cover bedrock in the valleys to a greater depth.

Figure 8 presents USGS regional geologic mapping along the alignment; more detailed mapping still needs to be done. Detailed logging and photodocumentation of the drill core is presented in Technical Memorandum A. Details of the water pressure testing are presented in Technical Memorandum B. Details of the groundwater monitoring are presented in Technical Memorandum C.

Bedrock Units

The foundations of DWR saddle dams number 1 through number 9 are composed of interlayered beds of Upper Cretaceous sandstone, siltstone, mudstone, and conglomerate of the Boxer Formation. In general, mudstone is the most abundant unit along the northern reservoir rim, comprising about 70 percent, with sandstone 25 percent, and massive conglomerate units 5 percent. The proposed dam alignments trend at various orientations across these sedimentary rocks and locally have different percentages than the regional average. The beds trend from N5°W to N10°W and dip from 60 to 80 degrees east near DWR saddle dam number 1, then altering northwestward to 10 to 35 degrees west near DWR saddle dam number 9. Although not mapped by USGS, the northerly trending Sites anticline probably extends northward adjacent to the Salt Lake fault, and this variation in dip is a reflection of this structure.

USGS mapped the area of the saddle dams with bedrock units that were differentiated into mappable units as follows (Figure 7) :

- Unit 7a - sandstone of the Boxer Formation,
- Unit 7b - interbedded sandstone and siltstone of the Boxer Formation,
- Unit 7c - siltstone of the Boxer Formation,
- Unit 7d - lower conglomerate of the Boxer Formation,
- Unit 7e - upper conglomerate of the Boxer Formation,
- Unit 8a - sandstone of the Venada member of the Cortina Formation,
- Unit 8b - interbedded sandstone and siltstone of the Venada member of the Cortina Formation.

Where fresh, the sandstone unit is light to medium olive gray in color; and where weathered, yellowish brown. It is mostly a very fine to medium-grained well-sorted arkosic sandstone with a silt to clay matrix. Bedding is massive to cross bedded that outcrops in units ranging from less than a foot to tens of feet in thickness. It contains thin interbeds of siltstone and mudstone that range from laminar up to 5 feet in thickness. It is moderately to well indurated, moderately to slightly fractured, moderately hard to very hard and strong where fresh. Internal structure is well developed in the areas of cross bedding and vague where massive. Calcite healing along fractures is common, with occasional pyritization.

The mudstone unit is dark gray to black in color where fresh and tan where weathered. Bedding is thinly laminar with thin sandstone and siltstone interbeds. It is brittle where exposed and slakes when exposed to air and moisture. It is moderately indurated to friable, moderately hard to weak, and closely fractured. It typically forms soils to a depth of 15 to 20 feet.

The conglomerate units are light to dark gray in color where fresh and buff to tan where weathered. The matrix is mostly silt to fine sand. The sub- to well-rounded clasts are composed of chert, volcanic, and metamorphic rocks. They range from pebbles to cobbles in size. Bedding is massive and outcrops in units ranging from 5 to 20 feet in thickness. It contains thin interbeds of siltstone and mudstone that range from laminar up to 5 feet in thickness. It typically is weathered from the surface to a depth of 20 feet. It is slightly fractured, moderately hard to very hard, and strong.

Unconsolidated Deposits

Unconsolidated deposits along the saddle dam alignments consist of soil, colluvium, alluvium and minor landslide deposits.

Colluvium occurs at the base of the steeper slopes and consists of soil, clayey silt and sand with angular rock fragments. This deposit also ranges from 2 to 5 feet in thickness.

Quaternary alluvium (Qal) is located at the SSD-1, SSD-3, and SSD-8 saddle dam sites. These are in the active stream channels of three southern tributaries to Hunters Creek and tributaries. They consist mainly of lean clay, silt, and poorly graded to well-graded sand, gravel, cobbles, and boulders. It occurs along the channel sides and as discontinuous deposits in the channel. Deposits are estimated to range up to 10 feet in thickness.

Numerous landslides have been mapped along the ridges on which the saddle dams would be built. Most of these are shallow earth slumps associated with steep mudstone slopes in the Boxer Formation. Some of these may also be associated with the Salt Lake fault zone or the adjacent Sites anticline. No deep seated or

bedding plane related failures have been mapped. None of these occur at or near a footprint of the proposed dam sites.

Structure

The primary structural feature along Sites' northern saddle dam alignments is the Salt Lake fault and the probably associated Sites anticline. Northerly striking, east-dipping homoclinal bedding of the Great Valley sequence has been folded by the Salt Lake fault to vary the dip of the bedding from 70 degrees west to 80 degrees east. This is complicated by associated northeast-trending tear faults that also cut across structure. As the alignments for SSD-8 and SSD-9 approaches the Fruto syncline to the west, the bedding dips from 10 to 20 degrees west.

Faults and Folds

USGS (Calif., Glenn and Colusa Counties 1961) mapped one major thrust fault and three northeasterly trending tear faults that intercept the proposed alignments for SSD-2, SSD-4, and SSD-5. The dominant fault is the Salt Lake fault, a major north-south trending thrust fault that is associated with the adjacent Sites anticline. The other five faults are northeast trending tear faults associated with the Salt Lake fault. The thrust is a northerly trending fault that extends from near the town of Sites to the south up to Antelope Valley, then attenuates about 10 to 15 miles to the north. The Salt Lake fault parallels the Sites anticline, a major doubly plunging, isoclinal anticline on the west side of Logan Ridge. The anticline and the Fruto syncline to the west extend a distance of some 40 miles. The Salt Lake fault is a high-angle reverse fault or a thrust fault that developed adjacent to the axis of the anticline. Salt water springs, gas seeps, and sag ponds on the fault trace suggest the possibility of recent fault activity. The salt-water springs and gas seeps may be a weakness along bedding planes, allowing the salt and gas an access to the surface from the deeper formations to the east under the Sacramento Valley. This high angle reverse thrust fault is mapped as immediately adjacent to the Sites anticline to the east and parallels its north/south trend. The presence of this potentially active fault in the foundation of SSD-2 is a concern. Since the fault is more likely a broad zone of deformation and shearing rather than a discrete surface trace, it is likely that it may also directly affect SSD-3 to the west and SSD-1 to the east. This fault is being studied in more detail by the consulting firm of William Lettis and Associates as part of the ongoing Sites-Colusa Reservoir Project fault and seismic investigation.

A significant north-south trending fault also crosses one of the saddle dams. This fault, mapped as the Salt Lake fault (Calif., Glenn and Colusa Counties 1961), trends along the axis of an anticline and is the subject of another current geologic investigation. The dip generally trends opposite directions on either side of the Salt Lake fault, and these variations in dip in the area of the saddle dams indicate that folding has occurred.

Folding and faulting is evident in the area of the saddle dams (Figure 7). At least three southwest-northeast trending right-lateral faults have been mapped at several locations (Calif., Glenn and Colusa Counties 1961). One crosses the ridge between SSD-6 and SSD-7, another through the SSD-6 axis, and the third through the small SSD-4 site. It is possible that unmapped minor tear faults exist that parallel these features. Beds have an apparent strike slip offset as much as 500 feet by some of these faults. A syncline is mapped to the west of the northern saddle dam alignments of SSD-8 and SSD-9. Instability occurs in the form of soil slips and shallow landslides throughout the general area.

Joints

At least two separate joint sets have been mapped along the alignment. The primary and most distinctive jointing strikes roughly east-west and has a northwesterly dip.

Foundation Conditions and Exploration

Staff at DWR's Northern District, San Joaquin District, and Division of Engineering performed a reconnaissance-level geologic investigation of the alignments for the saddle dam sites in fall 1998 and in spring and summer 1999. Work included review of 1963 and 1979 fieldwork by USBR and regional geologic mapping of the lithology, faults, and landslides in the area. Portions of the work and resultant report produced by the San Joaquin District (DWR 1999) are excerpted into this report. Diamond core drilling and augering was also performed in July 1999 at SSD-3 and SSD-6. Piezometers were placed in these drill holes, and monthly monitoring of the groundwater levels continues. USBR drilled 13 vertical diamond and auger holes at 11 saddle dike sites in 1979. These included holes at all nine of DWR-proposed saddle dam sites. Copies of USBR drill hole logs are included in Technical Memorandum A.

In spring 1999 the Northern District contracted with Layne-Christensen Drilling to provide drilling and testing services as part of this Sites Reservoir Project geologic investigation. Initial work was done at the Golden Gate outlet works; however, on July 22 the all-terrain CME-850 track mount rig was moved to the saddle dam sites. Three HQ diamond core drill holes and three auger holes were drilled from July 22 through August 4. Two of the drill holes and all three of the auger holes were drilled at SSD-3; an additional drill hole was placed at SSD-6. This was the final drilling at the project for the 1999 field season. Future drilling will depend on additional funding.

Following are summaries of the geologic conditions and additional work recommended for DWR saddle dam sites number 1 through number 9. Table 15

summarizes the foundation conditions and Table 16 summarizes the drilling footage.

DWR Saddle Dam Site Number 1

Proposed DWR SSD-1 is roughly equivalent to the location proposed by USBR for its dike 1. Actual footprints will vary slightly due to the differences in the proposed reservoir elevations.

USBR Dike 1

This dike, bearing N85°W, will have a maximum height of 50 feet and length of 585 feet. Surface is clayey topsoils underlain by mostly siltstones of the Boxer Formation. An area of soil creep is present on the slope above the right abutment, and a small landslide occupies the small drainage northeast of the right abutment. A more substantial area of instability with surficial landslides is in the drainage located about 300 feet southwest upstream of the left abutment. This should have no effect on the proposed structure. Small sandstone lenses outcrop on the left abutment. They strike about N20°W and dip 65 degrees east. USBR exploratory boring DH-100 is located near the maximum height of the structure. Drill logs record lean clay from the surface to a depth of 25 feet underlain by slightly weathered claystone to a depth of 34 feet. The claystone is thinly bedded with beds 100 to 500 millimeters thick. Thinly interbedded siltstone was also encountered. All rocks break with a light hammer blow. Bedding dips from 55 to 60 degrees. The rock from 29 to 34 feet is mostly very intensely to intensely fractured and contains clay gouge; rock fragments are slickensided. Shears dip approximately 10 to 20 degrees to bedding.

The USBR also performed water pressure testing in DH-100. Their analysis indicates a permeability of 10.6 meters per year in the interval from 25 to 34 feet (DOI-USBR 1969)". The hole was dry when drilling was completed.

TABLE 15 –Sites Reservoir Project, Northern Sites Saddle Dam Sites Foundation Conditions

FEATURE	SURFICIAL/BEDROCK GEOLOGY	CLEARING ESTIMATES	STRIPPING ESTIMATES	WATER LEVELS	GROUTING ESTIMATES	STRUCTURAL REMARKS
DWR Saddle Damsite #1 **USBR Dike #1** Alignment = N85°W Height = 50 feet Length = 585 feet USBR Drill Hole = DH-100 (located in the middle of saddle)	No distinction has been made between lithologic units inside dam footprint. foundation area = 101,400feet^2	LIGHT: Open grassy pastureland.	The upper 29 feet of soil, colluvium, and intensely weathered rock can be stripped using common methods. Interval from 29 to 34+? feet of moderately weathered rock may need to be excavated.	USBR DH-100 is dry upon completion of hole in Nov. 1979. In summer of 1999 no water levels were taken due to PVC stick-up missing.	USBR DH-100 shows that this hole is in impervious Ms from 25 to 34 feet.	Bedding strikes ~N20°W and dips from 55° to 65°E. This is a concern because dike structure will be constructed across strike of beds. Rock from 29 to 34 feet very intensely fx with gouge and slicks.
Saddle Damsite #2 **USBR Dike #2** Alignment = N67°E Height = 40 feet Length = 830 feet USBR Drill Hole = DH-101 (located 375 feet northwest of dam axis, outside of footprint)	No distinction has been made between lithologic units inside dam footprint foundation area = 161,100 feet^2	LIGHT: Open grassy pastureland.	The upper 32+? feet of soil, colluvium, and intensely weathered rock can be stripped using common methods. Drill hole was not deep enough to investigate any further.	USBR DH-101 measured 5.7 feet below ground surface upon completion of hole in Nov 1979. In summer of 1999 no water levels were taken due to PVC stick-up filled with dirt.	No water pressure tests taken.	Beds strike perpendicular to dam axis ~ N20°E to N20°W and dips from 64 to 80° E. The Salt Lake fault strike ~ N-S through this dam site.
Saddle Damsite #3 **USBR Dike #3** Alignment = N17°W Height = 130 feet Length = 4,600 feet USBR Drill Hole = DH-102 (located on dm axis in saddle) DH-103 (located on dam axis northern abutment) DWR Drill Holes= SSD3-1& SSD3-2 (located along dam axis), AUG-1, AUG-2, & AUG-3. (located along dam axis in saddle)	No distinction has been made between lithologic units inside dam footprint foundation area = 1,866,900 feet^2	LIGHT: Open grassy pastureland.	In the saddle the upper 18 feet of soil, colluvium, and intensely weathered rock can be stripped using common methods. Interval from 18 to 24 feet may need to be blasted and removed. Along the northern abutment the upper 47 feet of soil, colluvium, and intensely weathered rock can be stripped using common methods. Interval from 47 to 51+? feet of moderately weathered rock may need to be excavated.	USBR DH-102 measured 4.3 feet below ground surface upon completion of hole in Nov 1979. In summer/winter of 1999 water levels ranged from 8.6 feet to 7.3 feet respectively. USBR DH-103 measured 12 to 32 feet below ground surface during drilling and 35 feet below ground surface upon completion of hole in Nov 1979. In 1999 the depth has varied from 36 to 57 feet below ground surface.	USBR Drill Holes DH-102 and DH-103 show that both holes are impervious in predominately Ms with some Ss.	Possible fault crosses the northern quarter of structure. Possibly an unmapped section of the Salt Lake fault crosses the western side of the dam axis
Saddle Damsite #4 **USBR Dike #4** Alignment = N32°W Height = 19 feet Length = 350 feet USBR Drill Hole = DH-104 (located in saddle along dam axis)	No distinction has been made between lithologic units inside dam footprint foundation area = 23,600 feet^2	LIGHT: Open grassy pastureland.	The upper 12+? feet of soil, colluvium, and intensely weathered rock can be stripped using common methods. Drill hole was not deep enough to investigate any further.	USBR DH-104 was dry during drilling and during the summer and Nov. of 1999.	USBR Drill Hole DH-104 shows that it is in impervious in Ms.	Possible NE striking tear fault through center of dike (see figure 7).
Saddle Damsite #5 **USBR Dike #5 and #6** Alignment = N61°W Height = 106 feet Length = 3,000 feet USBR Drill Hole = DH-105 (located in the western channel on dam axis), DH-106 (located in eastern drainage next to road on eastern dam axis)	No distinction has been made between lithologic units inside dam footprint foundation area = 832,500 feet^2	LIGHT: Open grassy pastureland	The upper 13 to 20 feet of soil, colluvium, and intensely weathered rock can be stripped using common methods. An additional 12 to 14 feet of moderately weathered rock may need to be excavated.	USBR DH-105 Varied in depth to water table from 6.8 to 8.2 feet in 1979. Water level is now stable at 8 feet. USBR DH-106 varied in depth to water table 7 to 12 feet. The final depth reading was at 8.2 feet in 1979.	USBR Drill Holes DH-105 and DH-106 show that both holes are impervious in predominately Ms with some Ss.	Possible NE striking tear fault near DH-106. Another possible tear fault crosses ~500 feet to the SE of dam site (see figure 7). Northern abutment has bedded Cgl that strikes N15°W to N28°E and dips ~50° West.
Saddle Damsite #6 **USBR Dike #7** Alignment = N04°W Height = 70 feet Length = 560 feet USBR Drill Hole = DH-107 (located in right channel ~140 downstream of dam axis). DWR Drill Hole SSD6-1(located on southern edge of saddle along dam axis)	No distinction has been made between lithologic units inside dam footprint foundation area = 150,900 feet^2	LIGHT: Open grassy pastureland	The upper 10 to 19 feet of soil, colluvium, and intensely weathered rock can be stripped using common methods. An additional 6 to 10 feet of moderately weathered rock may need to be excavated.	USBR DH-107 depth to water table was ~6 feet during drilling. DWR Drill Hole SSD6-1 measured ~12 feet below ground surface.	USBR Drill Hole DH-107 show that it is impervious in predominately Ms with some Ss. DWR Drill Hole SSD6-1 shows high grouting takes to 22feet in Ss and Cgl. With no grouting requirements in the Cgl below 22 feet.	Abutments Consist mainly of Cgl and Ss beds. These units strike from N12°E to N30°W and dip 20 to 36° West. These units are predominately moderately to intensely fx.

Ss = Sandstone Ms = Mudstone Cgl = Conglomerate Qal = Quaternary Alluvium Qc = Quaternary Colluvium Qt_1 = Quaternary Terrace (lower) Qt_2 = Quaternary Terrace (upper) Fx = fracturing

TABLE 15 –Sites Reservoir Project, Northern Sites Saddle Dam Sites Foundation Conditions (continued)

FEATURE	SURFICIAL/BEDROCK GEOLOGY	CLEARING ESTIMATES	STRIPPING ESTIMATES	WATER LEVELS	GROUTING ESTIMATES	STRUCTURAL REMARKS
Saddle Dam site #7 **USBR Dike #7** Alignment = N76^{o}E Height = 30 feet Length = 400 feet USBR Drill Hole = DH-108 (located on saddle point in front of proposed saddle dam)	No distinction has been made between lithologic units inside dam footprint. Foundation Area = 42,100feet^{2}. Dam footprint still needs detailed mapping.	LIGHT: Open grassy pastureland.	The upper 15+? feet of soil, colluvium, and intensely weathered rock can be stripped using common methods. Drill hole not deep enough for further investigation.	USBR DH-108 is dry upon completion of hole in Sept. 1979. In summer of 1999 no water level were taken due to PVC stick-up missing.	No water pressure tests taken.	Dam axis will trend normal to strike of geologic units.
Saddle Dam site #8 **USBR Dike #8, #9, and #10** Alignment = N87^{o}W Height = 100 feet Length = 3,000 feet USBR Drill Hole =DH-109 (located on dam axis on left channel of eastern saddle of dam), DH-110 (located in middle channel of dam), and DH-111 (located on dam axis on western channel of proposed dam)	No distinction has been made between lithologic units inside dam footprint. Foundation Area = 1,163,600 feet^{2}. Dam footprint still needs detailed mapping.	LIGHT: Open grassy pastureland.	The upper 22 to 27 feet of soil, colluvium, and intensely weathered rock can be stripped using common methods. An additional 7 to 17 feet of moderately weathered rock may need to be excavated.	USBR DH-109 has ranged from being dry to 28 feet below ground surface. USBR DH-110 measured 10 feet below ground surface upon completion of hole in Oct 1979. USBR DH-111 has shown depth to water table ranging from 3 to 10 feet below ground surface.	USBR Drill Holes DH-109, DH-110 and DH-111 show that all three holes are impervious in predominately Ms with some Ss.	Dam axis will trend normal to strike of geologic units. Possible fault north of USBR Dike 10.Some flat beds possible indicating center of an anticline.
Saddle Dam site #9 **USBR Dike #11** Alignment = N68^{o}E Height = 20 feet Length = 600 feet USBR Drill Hole =DH-112 (located ~140 feet upstream of dam axis in channel)	No distinction has been made between lithologic units inside dam footprint. Foundation Area = 54,500 feet^{2}. Dam footprint still needs detailed mapping.	LIGHT: Open grassy pastureland.	In the saddle the upper 19.5+? feet of soil, colluvium, and intensely weathered rock can be stripped using common methods. Drill hole not deep enough for further investigation.	USBR DH-112 was dry upon completion of hole in Nov. 1979.	USBR Drill Hole DH-122 show that it is located in impervious Ms.	Dam axis will trend normal to strike of geologic units. Surficial landslide conditions along westward abutment.
Ss = Sandstone Ms = Mudstone Cgl = Conglomerate Qal = Quaternary Alluvium Qt_1 = Quaternary Terrace (lower) Qt_2 = Quaternary Terrace (upper) Fx = fracturing						

Table 16. Drilling footage of northern Sites saddle dams

Drill site	Drill hole	Date started	Date completed	Drilled footage (feet)
Northern Saddle Dam Alignment	SSD3-1	July 27, 1999	July 29, 1999	160.5
	SSD3-2	July 29, 1999	August 2, 1999	265.0
	SSD6-1	August 2, 1999	August 4, 1999	119.0
	Total HQ diamond drill footage			544.5
	AUG-1	August 4, 1999	August 4, 1999	14.0
	AUG-2	August 4, 1999	August 4, 1999	9.0
	AUG-3	August 4, 1999	August 4, 1999	21.5
	Total auger footage			44.5
	Total footage			589.0

LA = Left abutment drill hole
LC = Left channel drill hole
RC = Right channel drill hole
RA = Right abutment drill hole
DHPP = Drill hole power plant
DHS = Drill hole spillway
DHT = Drill hole tunnel
SSD = Sites saddle dam
AUG = Auger hole

A significant geologic concern at this site is that the dike structure will be constructed normal to the strike of the beds. Because the area has a thick soil cover, additional drilling and trenching may be required to better define the geologic conditions.

The upper 29 feet of soil, colluvium, and intensely weathered rock can be stripped using common methods. An additional 5 feet of moderately weathered rock may need to be excavated.

DWR Saddle Dam Site Number 2

The proposed DWR SSD-2 is roughly equivalent to the location proposed by USBR for its dike 2. Actual footprints will vary slightly due to the differences in the proposed reservoir elevations.

USBR Dike 2

This dike, bearing N67°E, will have a maximum height of about 40 feet and a total length of about 830 feet with a slight curve in the axis near the right abutment. Surface conditions consist of clayey soils with no rock outcrops mapped within the footprint of the dam. Thin sandstone and siltstone beds outcrop on the hillsides in the vicinity of the proposed dike. They strike N20°E to N20°W and range in dip from 64 to 80 degrees east. These beds are not continuous beyond 10 to 20 feet. USBR exploratory boring DH-101 drilled in 1979 is located beyond the footprint

of the dike and is approximately 375 feet north downstream of the dike axis in a small drainage. The log for this boring reports fat to lean clay with small amounts of silt and sand to a depth of about 17 feet. At about 17 feet, mostly intensely weathered sandstone with minor decomposed siltstone interbeds were encountered. This sandstone breaks with heavy manual pressure to light hammer blows. Weathered and fractured sandstone and siltstone continue to the bottom of the hole at about 31 feet. Groundwater was encountered at about 6 feet. No permeability testing was performed in this hole Like SSD-1, the axis of DWR's proposed saddle dam SSD-2 trends normal to the strike of the beds. It is recommended that drilling be performed to define the depth to bedrock and in-situ geologic conditions beneath the dam. This hole should be drilled along the axis where the maximum section occurs.

At least the upper 32 feet of soil, colluvium, and intensely weathered rock can be stripped using common methods. The drill hole was not deep enough to determine the extent of the underlying moderately weathered rock.

DWR Saddle Dam Site Number 3

The proposed DWR saddle dam site number 3 is roughly equivalent to the location proposed by the USBR for its dike 3. Actual footprints will vary slightly due to the differences in the proposed reservoir elevations.

USBR Dike Site Number 3

This is the highest of the saddle dams. Bearing N17°W, it closes the north end of Sites Reservoir, attaining a height of about 130 feet. This dike extends for more than 4,600 feet with four minor turns. Surface conditions vary from sandy to clayey rich soils, underlaid by sandstones, siltstones, and claystones of the Boxer Formation. Bedrock outcrops on the hillsides surrounding the structure consist of mainly discontinuous sandstone beds. They strike N20°E to N20°W and vary in dip from 55 to 67 degrees east. The maximum section is located in a shallow alluvial valley. Soils in the valley are fat to lean clays. A possible shear zone crosses the northern quarter of the structure. This fault is inferred by an alignment of small springs and wet areas, subtle breaks in topography, and an abundance of white calcareous rocks that appear as soil float. Two USBR drill holes were drilled in 1979 at this dike site. The southernmost, DH-102, was drilled in the alluvial valley near the center of the axis at the point of maximum section. The other, DH-103, was drilled in the northern quarter of the dike close to the potential shear zone. DH-102 was advanced to a total depth of 81 feet. It encountered alluvial material, mostly clay with some sandy clay and clayey sand, to a depth of 13 feet. The hole encountered mostly intensely fractured, decomposed to intensely weathered claystone. A limestone (calcareous sandstone?) bed was encountered at 18 feet. Bedding dips about 50 to 60 degrees to the west. At 63 and 68 feet two shear zones were encountered. They dip between 15 and 30 degrees and contained claystone fragments with dark gray clayey gouge. Slickensided bedding-plane partings were encountered between 70 and 72.5 feet. Four water tests indicated that permeability

(K) ranged from zero to 5.9 meters per year. Groundwater in 1979 was at a depth of 4.3 feet.

USBR drill hole DH-103 was advanced to a depth of about 50 feet. The top foot was a lean clay topsoil. Varying percentages of interbedded siltstones, claystones, and sandstones were encountered. Most of the rock was very intensely fractured. The claystones and siltstones mostly break with moderate to heavy manual pressure and the sandstones break with a light to moderate hammer blow. Bedding dips between 55 and 60 degrees. Water tests showed a permeability (K) of 0.5 and 8.9 meters per year in two tests. After hole completion, the depth to groundwater in 1979 was 35 feet. Some trenching may be required to verify the presence of the potential shear zone.

DWR angle drill hole SSD3-1 was drilled at a 45-degree angle to evaluate the stability of the Boxer Formation as foundation rock for Sites saddle dam number 3. It was also oriented to explore the possibility that an unmapped portion of the Salt Lake fault (three-quarters of a mile east) zone may pass through the footprint of the proposed dam. It was drilled to a total depth of 165.0 feet. It drilled through a clayey colluvial soil overburden to 7.0 feet. From 7.0 to 160.5 feet, it drilled through 60 percent sandstone with 40 percent mudstone interbeds. No significant shearing was encountered. The hole was not water pressure tested because of difficulties testing this angle hole. DWR angle drill hole SSD3-2 was drilled at a 45-degree angle to further explore the possibility that an unmapped portion of the Salt Lake fault zone may pass through the footprint of the proposed dam. It encountered 60 percent sandstone with 40 percent mudstone interbeds to the bottom of the hole. Again no significant shearing was encountered. Calculation of RQD's for both holes showed that in general, the foundation should have very poor rock quality from the surface to 20 feet vertical depth, then good to 22 feet. It then will be very poor to 34 feet, then poor to 50 feet, then good to 71 feet, then poor to fair to 80 feet (Table 17). This hole was not water pressure tested because of difficulties testing this angle hole.

Table 17. Rock Quality Designation in Drill Holes at Sites' Northern Saddle Dam Sites

Agency	Drill Hole	Vertical Depth (feet)	Min. RQD*	Max. RQD*	Avg. RQD*	Description
DWR	SSD3-1	10 22				No Recovery
DWR	SSD3-1	22 36	60	100	79	Good
DWR	SSD3-1	36 43	18	42	32	Poor
DWR	SSD3-1	43 47	100	100	100	Excellent
DWR	SSD3-1	47 72	0	78	47	Poor
DWR	SSD3-1	72 103	56	100	86	Good
DWR	SSD3-1	103 113	50	92	69	Fair
DWR	SSD3-2	18 28	0	6	2	Very Poor
DWR	SSD3-2	28 32	72	72	72	Fair
DWR	SSD3-2	32 49	0	36	17	Very Poor
DWR	SSD3-2	49 71	1	61	36	Poor
DWR	SSD3-2	71 102	56	84	72	Fair
DWR	SSD3-2	102 116	20	38	27	Poor
DWR	SSD3-2	116 120	98	98	98	Excellent
DWR	SSD3-2	120 128	0	0	0	Very Poor
DWR	SSD3-2	128 177	26	96	68	Fair
DWR	SSD3-2	177 187	0	42	20	Very Poor
DWR	SSD6-1	14 19	40	40	40	Poor
DWR	SSD6-1	19 119	94	100	99	Excellent

*Rock quality designation (RQD) is developed by summing the total length as measured along the centerline of the drill core recovered in each run, but only those pieces of core which are at least 4 inches in length are counted that are "hard and sound." The sum is then represented as a percentage over the length of the run.

Auger holes SSD3-AUG1, SSD3-AUG2, and SSD3-AUG3 were augered on August 4, 1999, to evaluate depths to bedrock, and the soil overburden along the axis of saddle dam site number 3 (Photo 28). The overburden consisted of a grayish brown silty, sandy clay with low plasticity, high toughness, and of medium strength when dry. Depth to bedrock ranges from about 5 to 20 feet.

The upper 18 feet of soil, colluvium, and intensely weathered rock in the valley can be stripped using common methods. The moderately weathered rock from 18 to 24 feet may need to be excavated. Along the northern abutment the upper 47 feet of soil, colluvium, and intensely weathered rock can be stripped using common methods. Moderately weathered rock from 47 to 51 feet may also need to be excavated.

Photo 28. CME-850 drill rig at angle hole SSD-3 at northern Sites saddle dam number 3

DWR Saddle Dam Site Number 4

The proposed DWR saddle dam site number 4 is roughly equivalent to the location proposed by USBR for its dike 4. Actual footprints will vary slightly due to the differences in the proposed reservoir elevations.

USBR Dike Number 4

Dike 4 occupies a small saddle, bearing N32°W; it has a maximum height of 19 feet and a length of approximately 350 feet. Surface conditions are clayey soils, with occasional sandstone and calcareous material appearing as float. No outcrops exist within the footprint of the structure. A potential fault has been mapped passing through the center of the dike. This fault trends northeast-southwest. It is mapped on the basis of springs and wet area alignments, alignment of subtle topographic breaks and linear features, and the occurrence of calcareous float. USBR drill hole DH-104, located near the center of the dike, was drilled to a depth of 12 feet. Surface conditions are a fat clay topsoil to a depth of about 2.5 feet underlain by interbedded claystones, siltstones, and occasional sandstone. Bedding dips from 40 to 60 degrees. Rock strength varies from breaks with manual pressure (siltstones and claystones) to breaks with a light hammer blow (sandstones). Calcareous healing is present in the soil and throughout the bedrock. A permeability test indicated tight conditions with no water loss. The hole was dry.

While the proposed structure is not of significant size and would not normally warrant additional geotechnical investigation, the occurrence of a potential fault trace may require some trenching.

At a minimum, the upper 12 feet of soil, colluvium, and intensely weathered rock can be stripped using common methods. The drill hole was not deep enough to determine the extent of the underlying moderately weathered rock.

DWR Saddle Dam Site Number 5

The proposed DWR saddle dam site number 5 is roughly equivalent to the locations proposed by USBR for its dike 5. Actual footprints will vary slightly due to the differences in the proposed reservoir elevations.

USBR Dike 5

Dike 5, bearing N61°W, will have a maximum height of 106 feet and a total length of more than 3,000 feet with three bends in the alignment. The dike will encompass two small valleys and two small saddles connecting five hills. Surface conditions are sandy to clayey soils with a few scattered rock outcrops. Rock outcrops in the southern area of the dike consist of thin to medium bedded sandstones and siltstones. Bedding strikes N12°W to N27°E and dips 34 to 55 degrees west. The northern end of the dike abuts a ridge and traverses along the ridgeline where a massive to thickly bedded conglomerate unit crops out. Bedding in the conglomerate strikes N15°E to N28°E and dips about 50 degrees west. Two USBR drill holes were drilled at the site, one on the axis and one downstream. They are located in the two areas of maximum section where the dike crosses the small valleys. Drill hole DH-105 was drilled to a depth of 60 feet. Fat clay soils are reported to a depth of 12 feet. From 12 to about 20 feet, decomposed and intensely weathered sandstone of the Boxer Formation was encountered. Bedding dips about 60 degrees. The sandstone is moderately weathered from 20 to 30 feet and slightly weathered below 30 feet. Below 31 feet, the hole encountered mostly interbedded siltstones and claystones. Most of the rock recovered above 30 feet was very intensely to intensely fractured. The core breaks with light manual pressure to light hammer blows. Permeability (K) was tested from 32 to 54 feet and was reported at 35 meters per year. Depth to water stabilized at 8 feet below the surface.

USBR drill hole DH-106 is located in the more northern valley of Dike L-5 and was drilled to a depth of 53 feet. Clay surface soils exist to a depth of 3.5 feet. The remainder of the hole is described as sandstone with interbedded claystone, and dips range from 45 to 50 degrees. The sandstone is intensely weathered to 13 feet, moderately to 21 feet, and slightly weathered to 26 feet. Fracturing varies from very intensely to slightly, directly correlating with the weathering breaks. The core breaks with moderate manual pressure to light hammer blows. Permeability (K)

was tested in the fresh rock from 37 to 53 feet and ranged from zero to 29 meters per year with a variable head. The final depth to water reading in 1979 was 8.2 feet.

Additional geological investigation at the saddle dam site number 5 is recommended at the northern end where the conglomerate is present. Permeability in the conglomerate has the possibility to transmit significant quantities of water. A drill hole should be drilled near the left abutment to test the permeability of the conglomerate.

The upper 10 to 19 feet of soil, colluvium, and intensely weathered rock can be stripped using common methods. An additional 12 to 14 feet of moderately weathered rock may need to be excavated.

DWR Saddle Dam Site Number 6

The proposed DWR saddle dam site number 6 is roughly equivalent to the locations proposed by USBR for its dike 6. Actual footprints will vary slightly due to the differences in the proposed reservoir elevations.

USBR Dike 6

This dike will be constructed at the head of a small drainage where the previously mentioned conglomerate unit crops out. The dike has a bearing of N4°W and is 73-feet high and 560-feet long. Surface conditions in the valley consist of mostly fat clay soils, while abutments are strewn with cobbles weathering out of the conglomerate unit. The abutments consist of mainly conglomerates and sandstones. These units strike from N12°E to N30°W and dip from 20 to 36 degrees west. The sandstone and conglomerate outcrops are strong and break only with a strong hammer blow, but are intensely to moderately fractured. USBR drill hole DH-107 is located in the valley about 250 feet downstream of the dike axis. This drill location is stratigraphically lower than the conglomerate or the sandstone present at the abutments. The drill hole log reports fat clay to a depth of 5 feet, underlain by interbedded claystone (75 percent) and sandstone to a depth of 40 feet dipping about 30 degrees. Weathering in the claystone ranges from decomposed near the surface to fresh below 29 feet and is thinly bedded. The sandstone bedrock encountered in the drill hole breaks with a moderate hammer blow. Most of the rock is intensely fractured. No permeability tests were performed. Groundwater in 1979 was at 8.2 feet below the ground surface.

Vertical DWR drill hole SSD6-1 was drilled to evaluate the engineering characteristics of the conglomerate as foundation rock for saddle dam number 6 (Photo 29). It was drilled to a depth of 119.0 feet. It encountered a clayey colluvial soil from 0 to 9.2 feet. From 9.2 to 16.1 feet, it drilled through 100 percent sandstone. From 16.1 to 119.0 feet, it drilled through 75 percent conglomerate

with 25 percent sandstone interbeds. Water pressure testing indicated that the conglomerate rock is very tight. Permeabilities in this zone average 1.73 feet per day.

The upper 10 to 19 feet of soil, colluvium, and intensely weathered rock can be stripped using common methods (Table 17). An additional 6 to 10 feet of moderately weathered rock may need to be excavated.

Additional geological exploration is recommended. Another hole should be placed upstream of the proposed dike to further evaluate the permeability of the massive conglomerate and sandstone.

Photo 29. DWR drill hole SSD6-1 at Sites saddle dam site number 6

DWR Saddle Dam Site Number 7

The proposed DWR saddle dam site number 7 is roughly equivalent to the location proposed by USBR for its dike 7. Actual footprints will vary slightly due to the differences in the proposed reservoir elevations.

USBR Dike 7

Dike 7 straddles a small saddle bearing N76°W and trends normal to the strike of the geologic units. It is about 30 feet high and 400 feet long. Surface soils consist primarily of fat clay with no rock outcrops in the immediate area of the dike. Outcrops of a conglomerate unit, located about 100 feet east of the right abutment, strike N6°W to N12°W and dip 29 to 35 degrees west. A small outcrop of sandstone west of the left abutment strikes N6°E and has a questionable dip of 4 degrees west. USBR drill hole DH-108 is located on the east side of the dam, or

the right abutment, and was completed to a depth of 15 feet. The drill hole log indicates fat clay to about 5 feet with decomposed claystone to 12 feet and intensely weathered sandstone to the bottom of the hole. Bedding dips upstream at 30 degrees. The sandstone breaks with heavy manual pressure to light hammer blows. The hole was dry, and no permeability testing was performed.

The only additional geologic work that may be necessary at this site is trenching.

The upper 15 feet of soil, colluvium, and intensely weathered rock can be stripped using common methods. The drill hole was not deep enough to determine the extent of the underlying moderately weathered rock.

DWR Saddle Dam Site Number 8

The proposed DWR saddle dam site number 8 will be at least 4,000 feet long and will be placed roughly equivalent to the locations proposed by USBR for its dike 8, dike 9, and dike 10. Actual footprints will vary slightly due to the differences in the proposed reservoir elevations.

USBR Dike 8

Dike 8, bearing N87°W, is about 35 feet high. It extends about 600 feet from a hilltop near the left abutment of saddle dam site number 7 across a small saddle and onto another hill to the west. Surface soils range from fat clays to sandy clays. There are no rock outcrops within the footprint of the dam. However, significant amounts of sandstone float were found near the left abutment. One sandstone outcrop on the hillside south of the dam had a strike of N6°E and a dip of 24 degrees west. The sandstones appear to be thickly bedded to massive and break only with a strong hammer blow. The degree of fracturing was indeterminable. USBR drill hole DH-109, located 250 feet downstream of the right abutment of SSD-8, was drilled to a depth of 31 feet. The log reports fat clay to a depth of 8 feet and claystone from 8 feet to the bottom of the hole that varies from intensely to moderately weathered and intensely fractured. The beds dip about 30 degrees. Permeability (K) was tested from 15 to 31 feet and had a take of 7.6 meters per year. The hole was dry.

As at saddle dam site number 7, the axis proposed for DWR saddle dam SSD-8 trends normal to the strike of the geologic units. It is recommended that some trenching be performed to better define the subsurface geologic conditions.

USBR Dike 9

Dike 9 crosses a broad alluvial valley bearing N87°W, then turns and connects two small hilltops along a ridge. The proposed structure would have a maximum height of about 100 feet and a total length of about 2,300 feet. Surface conditions are clayey sand topsoil on the hillsides and mostly clayey alluvial soils in the valley. Rock outcrops within the dike footprint are scarce. The hilltops and hillsides displayed considerable amounts of sandstone float. Rock outcrops near the right abutment strike N6°E and dip 24 degrees west. Near the left abutment, an outcrop strikes N5°E and dips 10 degrees west. These outcrops are comprised of thickly bedded to massive sandstones. They are moderately strong, breaking with a moderate hammer blow. Mudstone and sandstone outcrops in a creek about 600 feet south of the left abutment strikes N7°W, dipping 13 degrees west. This creek outcrop is composed of about 80 percent mudstone and 20 percent sandstone. USBR drill hole DH-110 is located in the alluvial valley some 300 feet downstream of DWR drill hole SSD-8. It had a total depth of 66 feet. The top 16 feet is alluvial material consisting of lean to fat clays, clayey sands, and sandy clays. The remainder of the hole encountered mostly (75 to 90 percent) claystone interbedded with minor amounts of sandstone. The beds dip about 25 degrees. The rock weathering varies from decomposed to slightly weathered and is mostly intensely fractured. The claystones break with moderate to heavy manual pressure, while some of the sandstone interbeds break with a light to moderate hammer blows. Permeability testing from 30 feet to the bottom of the hole indicated a permeability (K) of 18.2 meters per year. The stabilized depth to water in 1979 was about 10 feet.

It is recommended that augering and drilling be performed along the axis to better define the depth to bedrock near the abutments and the alluvial valley. Seismic surveys may assist in defining this contact.

USBR Dike 10

Dike 10, also bearing N87°W, would have a maximum height of about 60 feet and a total length of about 1,030 feet. The axis trends from a hilltop across a small valley to a second hill, crossing a saddle, and terminating on a third hilltop. There are no rock outcrops within the dike footprint or adjacent to it. The middle and left hills contain scatterings of sandstone float. A sandstone outcrop on a hill north of the right abutment strikes north-south and dips 40 degrees west. The sandstone is very hard and massive, and it breaks with very heavy hammer blows. A second sandstone outcrop, located just north of the left abutment, strikes N60°E and dips 28 degrees west. This sandstone outcrop is massive and strong. Fieldwork performed by DWR's Northern District in 1998 revealed a potential fault north of the dike. The fault was mapped on the basis of a break in slope and the alignment of several springs. This fault does not appear to cross the dike axis. USBR drill hole DH-111 is located on the SSD-8 axis in the valley at the maximum section of the proposed dike. From the ground surface to a depth of 21 feet, the hole encountered

alluvial soils consisting of fat and lean clays. Below 21 feet to the hole bottom at 38 feet are predominately (95 percent) claystones with occasional siltstone interbeds. The rocks are thin to medium bedded, intensely weathered to fresh, and very intensely fractured. Bedding dips 15 degrees. These flat beds are indicative of the Fruto syncline as mapped by USGS (Calif., Glenn and Colusa Counties 1961). Fresh rock near the bottom of the hole breaks with light hammer blows along bedding plane partings. Permeability testing of the interval from 27 to 38 feet was 7.84 meters per year. Depth to water in 1979 was 3.3 feet below the land surface.

The upper 22 to 27 feet of soil, colluvium, and intensely weathered rock can be stripped using common methods. An additional 7 to 17 feet of moderately weathered rock may need to be excavated.

The axis of the dike trends normal to the strike of the geologic units. Obtaining additional information will require more drilling and trenching. At a minimum the right half of the dam alignment should be trenched to evaluate foundation conditions. If bedrock cannot be reached by trenching, a drill hole will be necessary. Additional geologic evaluation of the mapped fault should also be considered.

DWR Saddle Dam Site Number 9

The proposed DWR saddle dam site number 9 is roughly equivalent to the location proposed by USBR for its dike 11. Actual footprints will vary slightly due to the differences in the proposed reservoir elevations.

USBR Dike 11

This dike would trend S68°E with a height of about 20 feet and a length of about 600 feet. Surface conditions at the right abutment show scattered sandstone float and clay soils. There are no rock outcrops on the right abutment. USBR alignment crosses a small drainage that contains fat clay soils and occasional wet spring areas. An exposure of mudstone in the drainage has a strike of N9°E and a dip of 8 degrees west. The left abutment of USBR alignment keys into a hillside. On this hillside, about 40 feet above the dam crest, is a prominent sandstone outcrop. This sandstone unit is continuous for several hundred feet north and south of the abutment. The sandstone bed is about 2 feet thick and very hard. It breaks only with a heavy hammer blow and strikes N17°E and dips 6 degrees west. The DWR alignment crosses a saddle south of the USBR alignment. Soils in the saddle are predominantly clay. The left abutment hillside shows signs of instability in the form of landslide activity as displayed by hummocky topography. Sandstone clasts are imbedded in the landslide material. There are no in-place rock outcrops along this alignment. USBR drill hole DH-112, drilled to a depth of 19 feet, is located near the right abutment of the USBR alignment. DH-112's location appears to be near the upstream toe of DWR axis. The top 2.5 feet consist of lean clay alluvium. The interval from 2.5 to 11 feet is decomposed claystone. From 11

to 19 feet are interbedded claystones and siltstones, with a trace of a cemented sandstone interbed at 13 feet. The beds dip from zero to 5 degrees. The rock core breaks with light to moderate manual pressure in the decomposed claystone, light to moderate hammer blows in the less weathered claystones, while the sandstones require heavy hammer blows to break. Permeability was tested in the interval from 10 feet to 19 feet and determined to be 5.33 meters per year. The hole was dry.

In the saddle dam site, the upper 19.5 feet of soil, colluvium, and intensely weathered rock can be stripped using common methods. The drill hole was not deep enough for further investigation.

Both of the above alignments trend normal to the strike of the beds. Another drill hole in the valley is recommended to determine the maximum thickness of alluvial sediments. Careful attention should be paid to the instability along the left abutment of the DWR alignment due to the surficial landslide conditions.

Conclusions and Recommendations

The rock at Sites' northern saddle dam alignments should provide acceptable foundations for the proposed saddle dams with moderate stripping. However, several concerns exist:.

- Very few rock outcrops exist within the proposed saddle dams sites. This makes it difficult to determine foundation conditions. More drilling and trenching will be required prior to construction.

- Several of the dam axes that trend normal to bedding may create avenues for seepage.

- Although the conglomerate appeared to be tight when drilled and tested at saddle dam site number 6, this does not mean that it will be the same when it is encountered in the foundations for saddle dam sites number 5 and number 7. Additional work may be needed to evaluate these sites.

- The presence of fault or fracture zones crossing saddle dam sites may create foundation and/or permeability problems that need further evaluation. Also, the possibility that the Salt Lake fault and tear faults intercept the alignment needs to be further evaluated.

- Seismic refraction surveys and auger holes may be supplemented to determine stripping and rippability.

- Map all landslides in the vicinity of the dam axes.